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RESEARCH ARTICLE

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Utility of collaborative GIS for maritime spatial planning: Design and evaluation of Baltic Explorer

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Abstract

Maritime spatial planning (MSP) needs tools to facilitate discussions and manage spatial data in collaborative workshops that involve actors with various backgrounds and expertise. However, the reported use of spatial tools in real-world MSP is sparse. A better understanding is needed of how geographic information systems (GIS) can effectively support collaboration in MSP. We studied the utility of GIS tools for collaborative MSP in five steps: first, identifying shortcomings in available GIS for supporting collaborative MSP; second, defining requirements for an effective collaborative GIS (CGIS) for MSP; third, designing and developing a prototype CGIS, Baltic Explorer; fourth, demonstrating the system; and fifth, evaluating the system. In a real-world MSP workshop, we demonstrated that the functionalities of Baltic Explorer can support and facilitate discussions in collaborative work. We also found that more research is needed about the use of spatial data in collaborative MSP and integration of model-based geospatial analysis into CGIS.

1 | INTRODUCTION

Maritime spatial planning (MSP) is "a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that usually have been specified through a political process" (Ehler & Douvere, 2009). Collaboration is central to the success of MSP.

The European Parliament and Council Directive 2014/89/EU (European Union, 2014), establishing a framework for MSP and issued in 2014, requires that MSP plans of EU member states are developed in cooperation with other states and that stakeholders are involved in the process. Stakeholder involvement is also considered the backbone of successful ecosystem-based MSP processes, ensuring that ecosystem goods and services are properly maintained (Ansong, Gissi, & Calado 2017). It needs to be cross-sectoral and include the sectors that are affected by the plan (Ansong et al., 2017). These requirements present new challenges for government organisations in charge of implementing MSP, as they need to reach out to organisations beyond their national borders and collaborate in a multidisciplinary scenario.

Spatial data is inherently intertwined in all phases of the MSP process. MSP actors agree that data should come from a variety of sources, including less traditional non-government sources (Gopnik et al., 2012). Traditional geographic information systems (GIS) tools are typically used to manage spatial data in MSP. GIS tools developed specifically for use in MSP tend to be model-based spatial decision support tools (SDSS) that support planners in analysing spatial relations, conditions and phenomena. Flannery and Ó Cinnéide (2012) argue that collaboration in MSP initiatives through face-to-face interaction and constructive dialogue between stakeholders produces beneficial outcomes that are unlikely to develop through other methods. Collaboration can also build trust and understanding between stakeholders (Flannery & Ó Cinnéide, 2012). Both conventional GIS and model-based SDSS face multiple challenges in effectively facilitating discussion in such settings. While terminology describing the nature of GIS is somewhat fuzzy, GIS that support collective planning and decisions can be aggregated under the name of participatory GIS (PGIS; Balram & Dragicevic, 2006). PGIS have a locational and temporal dimension, meaning that they support participation either at the same or different time and location (Armstrong, 1993). It has been argued that interaction between stakeholders is important for a collaborative MSP approach and cannot be solely achieved through methods where users collaborate in different location setting (Alexander et al., 2012).

Collaborative GIS (CGIS) can be viewed as a subset of PGIS, defined by Balram and Dragicevic (2006) as "an eclectic integration of theories, tools and technologies focusing on, but not limited to, structuring human participation in group spatial decision processes". Results achieved through the use of CGIS come from a joint and structured exploration of ill-defined problems rather than a task-oriented approach (Balram & Dragicevic, 2006).

Reviews of MSP tools in the literature (e.g. Pınarbaşı et al., 2017) show that there are relatively few CGIS designed for MSP workshops. A CGIS to support stakeholder involvement, BaltSeaPlan Web, was developed in the BaltSeaPlan project (Fetissov, Aps, & Kopti, 2011). Its visualisation capabilities were reported to be effective at supporting participatory processes in the integration of fishery management into the process MSP (Kopti, Aps, Fetissov, & Suursaar, 2011). However, the reported use of the system since then is limited, as is documentation in the scientific literature validating its usefulness for collaboration in MSP.

In real-world MSP workshops, planners often still opt to use paper maps to share and discuss issues related to spatial data. Users with limited experience with computerised systems may prefer tools on paper (Rose et al., 2016). However, a well-designed CGIS can improve the effectiveness of capturing, storing, analysing, visualising and exploring spatial data in a group collaboration. As concerns have been expressed about the suitability of model-based tools in collaborative settings of decision-making processes (e.g. Ramsey, 2009), and with CGIS for MSP being few in number, as well as a lack of use of GIS in collaborative MSP, there is not enough knowledge available for useful CGIS for MSP. This knowledge needs to be developed to enhance collaboration in MSP.

The usefulness of a software system can be viewed as the sum of its utility and usability (Nielsen, 1994). A system's utility can be described as its ability to perform tasks it is designed for (Sidlar & Rinner, 2009). Usability indicates how easy it is for its users to perform the tasks the system is designed for (Johannesson & Perjons, 2014). As usability depends on the functionalities, which depend on their utility for the task the system is designed for, the first step in designing useful CGIS for MSP is to understand the utility of various system properties for MSP.

In this article, we present results from studying the utility of CGIS for facilitating discussion in MSP workshops. The aim of the study is to develop knowledge that can be applied in developing useful functionalities in CGIS that enhance same location, same time collaboration with maps in MSP. Second, the study aims to identify remaining gaps in knowledge about CGIS for MSP. Section 2 describes the principles of design science research and its application in the context of designing CGIS for MSP. Section 3 focuses on explicating the problem of why current GIS systems are not suitable for same location, same time collaboration in MSP. Section 4 presents identified requirements for CGIS in MSP. Section 5 presents the design and development of a prototype system, Baltic Explorer. Section 6 presents the results from a demonstration and evaluation of the system. Section 7 discusses the meaning of the results and presents suggestions for future research on CGIS for MSP as well as possibilities for expanding the utility of a designed system for purposes other than MSP workshops. Section 8 presents the conclusions of the study.

2 | METHODS

2.1 | Overall research method

We based our method on the design science research (DSR) framework. DSR is a methodological approach to perceiving a real-world problem, designing and developing a solution for the problem and then studying the solution (Dresch, Lacerda, & Antunes, 2015). DSR makes prescriptive scientific contributions that present knowledge about artefacts (e.g. prototype systems) (Johannesson & Perjons, 2014).

We adopted a five-step method for the study, based on the DSR framework (Figure 1). In the first step, *problem explication*, we identified the issues that are faced when using existing GIS applications to facilitate discussions in collaborative MSP. We elicited knowledge from the scientific literature on GIS used in collaborative settings for MSP workshops and other similar settings. In the second step, *specification of requirements*, we used the knowledge from the previous step to set the requirements for CGIS in MSP. We also elicited additional knowledge from the scientific literature about successful features in CGIS aimed at MSP workshops and other similar settings. In the third step, *design and development*, we used the requirements to design a CGIS for MSP that we named Baltic Explorer. We then developed an implementation of the design, the Baltic Explorer prototype CGIS. The second and third steps were carried out iteratively, as challenges in development required a refinement of the requirements of the system. In the fourth step, *demonstration*, we tested the Baltic Explorer prototype in a real-world use case to demonstrate that the system works as intended. In the fifth step, *evaluation*, we assessed the design based on naturalistic observation and questionnaires that users completed during the real-world workshop. Additionally, a second user test was conducted in a controlled environment, using a fictional use case to study users' preference for different devices when using the system.

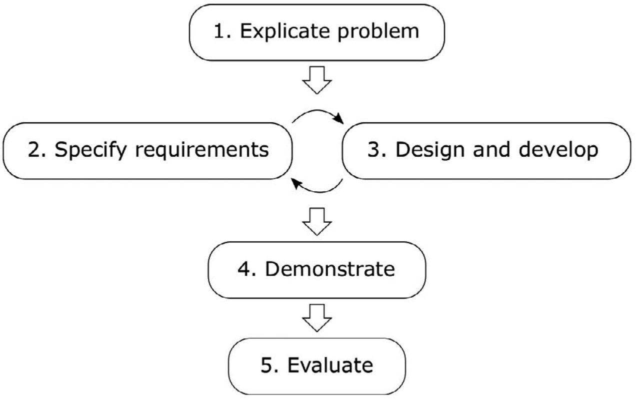

FIGURE 1 The five steps of the method used in the study

2.2 | Real-world MSP workshop

We demonstrated the developed prototype system at a real-world MSP workshop in Umeå, Sweden. The Umeå workshop was organised by the Pan Baltic Scope project. The workshop participants were MSP planners, industry representatives, scientists and experts from Sweden and Finland. During the workshop, participants joined a session where they discussed planning objectives, available data and other issues. Discussions were facilitated by the Baltic Explorer prototype. Participants were divided into two groups of about 15 people each, and both groups had their own session space. Baltic Explorer was used through a large shared screen (PC and projector), as well as participants' personal devices. A planner led the discussion in both groups. One person took the role of system moderator, who controlled Baltic Explorer on the large screen. The sessions lasted for an hour. After the sessions, participants were handed a questionnaire to complete about functionalities in collaborative systems and Baltic Explorer. Data on the usefulness of the system's properties for collaborative MSP was collected through naturalistic observations and a questionnaire about the helpfulness of functionalities in the system for varying tasks. The same question was also asked about the helpfulness of functionalities that were not implemented but could potentially benefit the workshop participants.

2.3 | Controlled environment user test

A second user test was conducted in a controlled environment. The aim of the controlled environment user test was to develop knowledge on the role of personal and shared devices in CGIS. This knowledge is critical to the development of CGIS because platforms require suitable interfaces that are tailored to their screen sizes and input methods. Because such a test requires specific devices for the users, we carried out the test in a controlled environment. Such a test in a real-world environment would have required us to interfere with how planners wanted to set up the workshop, and to limit some participant's options to interact with the system by limiting available devices. The use case was fictional and gamified, and aimed to simulate typical tasks in MSP workshops.

The participants in the controlled environment user test were divided into groups of three people who assumed the roles of actors representing an environmental protector, and representatives of both the energy and tourism industries. There were 18 participants divided into six groups. Two groups used personal laptops, two groups shared a single device with a large screen, and the remaining two groups used both types of devices. Nine participants were PhD students taking part in an MSP course and the other nine participants were professionals working in the geospatial sciences. The users were equally distributed to different device set-ups based on their backgrounds. Users played a game on the Baltic Explorer prototype where they competed for control over 17 sea areas on a map. The value of each area for each industry was given to the participants, ranking each area for each participant on a five-step scale from "no value" to "excellent value". Participants were then asked to perform four tasks. First, they would prepare a presentation on their areas of interest for other participants. Second, they would present their interests. Third, while the other participants presented their interests, participants would build their insight into the presenters' interests. Fourth, the participants would collaborate to find a compromise solution where no conflicts of interests existed on the map. After the user test, participants were asked to complete a questionnaire about the use of the available devices with the Baltic Explorer prototype.

3 | PROBLEM EXPLICATION

The aim of the first step of the study, problem explication, was to identify the issues faced when using existing GIS applications for facilitating discussions in collaborative MSP. We summarise the results of this step in a root-cause diagram depicting how the issues relate to different elements of the system (Figure 2).

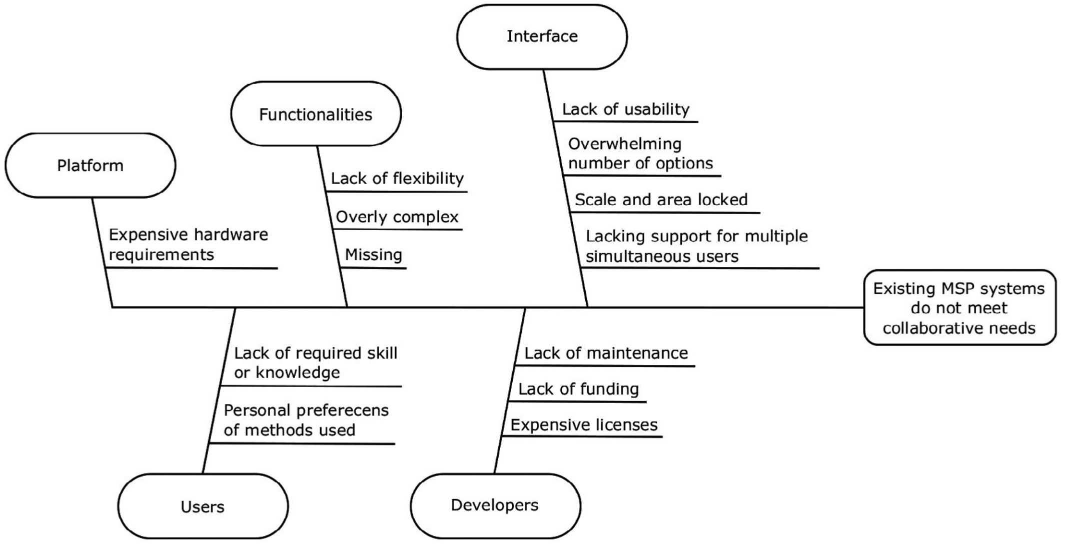

FIGURE 2 Root-cause diagram visualising how issues in existing systems relate to different elements of CGIS

Participants in MSP workshops typically have limited technical skill and experience with GIS software. Therefore, participatory tools designed for non-expert users need to be simple and easy to use (Arciniegas & Janssen, 2012; Pınarbaşı et al., 2017). This is often not the case with commonly used GIS and spatial applications for MSP. For example, traditional GIS incorporate a variety of complex functionalities for single users and narrow the effectiveness of task-solving (Rauschert et al., 2002). They are considered to be too complex for non-expert users (Merrifield et al., 2013). Likewise, GIS tools in MSP tend to be SDSS that are based on complex models not well understood by participants in MSP workshops. Ramsey (2009) argued that because model-based SDSS pre-define the problem and pre-conceptualise the problem space through their models, they are useful only if workshop participants already agree on the definition of the problem and conceptualisation of the problem space. Ruiz-Frau et al. (2015) propose that a way to connect the scientific models with collaborative MSP is to use the resulting map layers from science-based analyses as a basis for discussion when collaborating with stakeholders. Ramsey (2009) suggests that each self-affiliating group works with a GIS expert in advance to construct a unique model with no limitations on how the problem can be defined; and once the result can be visualised and spatialised and the group is satisfied, the result is brought to the collaborative forum. The models are then discussed in the collaborative setting to agree on what the final model should be (Ramsey, 2009). These findings suggest that complex model-based functionalities should not be part of CGIS as such. Rather CGIS should have the means to access and visualise the resulting data from the analyses.

However, there are also studies that support the integration of model-based tools in CGIS. For example, Armstrong (1994) argues that while tailoring CGIS to a specific problem may have adverse effects on a system's flexibility, it may help the system to perform the tasks that decision-makers need. It therefore remains unclear to what degree analysis tools can be successfully included in CGIS for MSP workshops, and, perhaps more intriguingly, how these tools should consider the user's limited skill and knowledge about GIS and the models that are used. Education and training—in addition to giving users time to play with tools before collaboration—have been suggested as solutions to overcome issues with tool complexity (Arciniegas, Janssen, & Rietveld, 2013). However, expecting users to take the time to learn to use a system in advance, or using a significant amount of workshop time to do so, may be unrealistic.

Model-based tools and conventional GIS also lack support for group work. Computer-supported group work should enable interactive collaboration among participants (Armstrong, 1994). Giving control to participants over actions with the used system increases the participants' sense of involvement, which in turn increases the transparency and acceptance of the planning process. There is also a need to support the varying roles of actors in the decision-making process (Andrienko et al., 2007).

Spatial decision problems are inherently ill-defined (Andrienko et al., 2007). There is a seemingly endless number of possibilities for different decision contexts, methods and needs of different organisations that may direct tasks with CGIS in collaborative MSP workshops. Group decision-making tools need to adapt to these varying conditions (Armstrong, 1993). MSP is also a multi-stage process where collaboration is needed at various stages. Existing tools for MSP focus on specific stages of the process, and many lack multi-functionality, resulting in infrequent use (Pınarbaşı et al., 2017). Model-based MSP tools have often been found to be tailor-made for specific use cases and thus may not be suitable for countries looking for tools to support their MSP efforts (Stelzenmüller, Lee, South, Foden, & Rogers, 2013). Ramsey (2009) goes into detail in discussing issues with pre-defined problems and tasks that model-based SDSS use to arrive at a solution. A suggested solution is to use flexible GIS applications that allow participants to explore the problem and come to a consensus on problem definitions. Andrienko et al. (2007) also note the need for interfaces to adapt to the skills and needs of users.

To gain widespread use, tools in MSP also need to be accessible. Aspects to consider include the cost of licences, hardware requirements, maintenance and funding. Cost has been found to be a key issue in taking decision support tools into use in real settings (Pınarbaşı et al., 2017; Rose et al., 2016). Typically, this relates to the cost of licensing the systems, but it can also relate to hardware requirements. For example, CGIS running on touch tables have been reported to be well received by participants (Arciniegas & Janssen, 2012), and CGIS on tangible tables have been reported to help non-expert users to better understand spatial data and analysis (Guerlain, Cortina, & Renault, 2016). However, such devices are rarely available for workshop organisers and are expensive to acquire. They also limit the number of simultaneous users (Arciniegas & Janssen, 2012).

4 | REQUIREMENTS

The aim of the second step of the study was to define requirements for CGIS in MSP workshops. Based on the findings from the first step, we were able to derive several general requirements for such systems. CGIS for MSP workshops should be simple, easy to use, adapt to different use cases, geographic areas and scales, support multiple users working together and be built for devices that are widely available or cheap to acquire. In addition, CGIS should feature useful functionalities that are not too complex. We studied the scientific literature further to identify and define what the functional requirements should be for CGIS in MSP.

4.1 | Managing spatial data and data availability

At the heart of all GIS is spatial data. Core GIS functionalities, capturing, storing, visualising and exploring spatial data have been found to support collaborative decision-making processes. For example, Alexander et al. (2012) achieved promising outcomes from using a CGIS to collect knowledge from local sea users through map inputs. Sun and Li (2016) state that CGIS require efficient data access, integration and management, in addition to mechanisms to handle outcomes from collaboration. Rose et al. (2016) found that non-expert users considered visual representation of data to be the best way to increase user-friendliness in a decision support tool. Likewise, Andrienko et al. (2007) explain that visualisation and interactive visual interfaces effectively provide material for human analysis and reasoning and are essential for supporting the involvement of humans in problem-solving. Ramsey (2009) emphasises the importance of enabling exploration of the problem, rather than using pre-defined models in collaborative settings.

MSP is cross-sectoral, which means that stakeholders may possess and be familiar with vastly different data. It is therefore important to support participants' use of their own data in collaborative settings by providing tools to visualise the data in CGIS. However, arguments and counterarguments using independent data can lead to more confrontation between participants because of inherent differences in the sources of the data (Balram & Dragicevic, 2006). Easy access to open spatial data, for example data in MSP spatial data infrastructures (SDIs), can help in accessing common data that can form the basis for discussion. MSP SDIs give users a wide range of data to use without the need to separately download and import the data into the system. This can also be used to overcome issues of sensitive data. Data owners or knowledge holders may be more willing to share data if they retain ownership and control of the data (Shucksmith & Kelly, 2014). Owners could enable access to the data through standardised SDI methods, which would enable the data to be viewed without the need to store it in the CGIS.

4.2 | Support for specific planning tasks

Planners may introduce various tasks in an MSP workshop to reach their goal for the collaboration occurring in the meeting. CGIS can provide tools to facilitate the tasks when spatial data is involved. However, the scientific literature is not explicit on what tasks MSP workshops include and how spatial data is used in these tasks. This makes it challenging to define a comprehensive set of functional requirements to sufficiently support the tasks and activities of MSP workshops. Nevertheless, these functionalities are required to allow planners to reach their goals. This is a major gap in the knowledge of building effective CGIS for MSP workshops. However, while this gap in the knowledge remains, developers can derive ideas from similar systems designed for other use contexts. For example, commenting on map features generated by other users and a means to have structured communication through the collaborative system have been used in online PGIS (Keßler, Rinner, & Raubal, 2005). Synchronous multi-user environments may require the means to identify content generated or added by different users (Sun & Li, 2016).

5 | DESIGN AND DEVELOPMENT

In the third step of the study, we designed and developed Baltic Explorer. The aim of the design was to provide a blueprint for an effective CGIS for facilitating discussions in MSP workshops. Design choices were based on the previous two steps of the study. The proposed system design has three interfaces: a login interface for users to log in and access workspaces, a multi-user map-based workspace interface where users collaborate during workshops, and an administration interface for workshop organisers to manage user accounts and data (Figure 3).

5.1 | Multi-user map environments

Armstrong (1994) suggests that CGIS should include virtual workspaces that propagate changes a user makes to other users, who may then react by making their own changes. The proposed design features map-based multi-user virtual workspaces where users collaborate through multiple devices (i.e. a workspace is accessible from multiple devices simultaneously), and changes made on any device are stored in a common database and can be synchronised on the other devices. Workspaces have simple, two-dimensional map interfaces with common map navigation functionalities (e.g. panning and zooming). Workspace progress is stored in the database, and multiple workspaces can be created by users within the system.

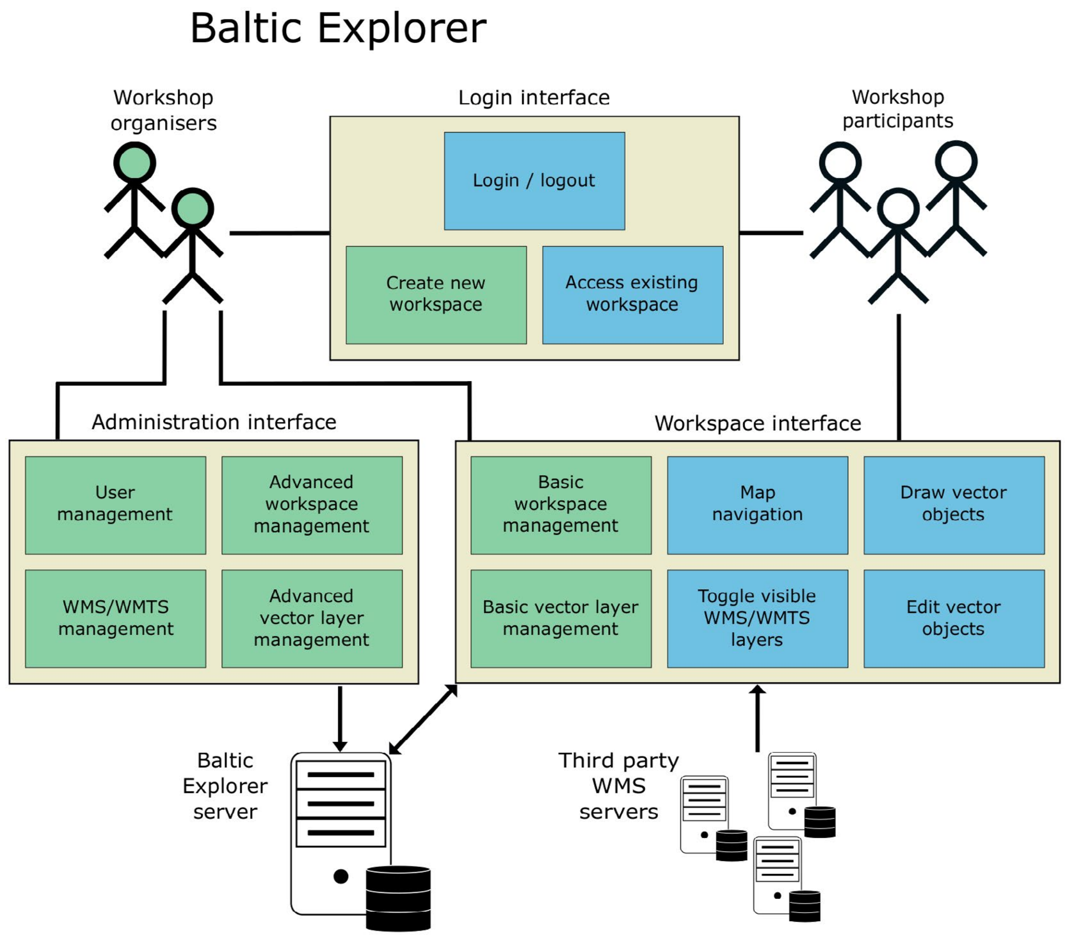

FIGURE 3 Baltic Explorer design. Functionalities in the green boxes are intended to be used by workshop organisers only

5.2 | Functionalities

The designed CGIS is communication-driven, with the aim of supporting and facilitating face-to-face discussions in workshop settings. The system achieves this through simple and easy-to-use spatial data management and access functionalities. Participants can draw new features on the map (points, lines, multi-lines, polygons, multi-polygons) with various style options. Features are stored in vector format in the systems database. Spatial vector data can also be imported into workspaces. The system enables all vector data in workspaces to be edited.

The system enables easy access to data in MSP SDIs using web map services (WMSs). WMS properties, such as the layer names and URLs, are stored in the system's database and used to generate an intuitive menu, where users can browse layers and add them to the workspace with a single click. Additional WMS layers can be added to the database through the administration interface. Likewise, the base map can be changed, and new base maps available through web map tile services can be added to the system. Workshop owners have control over which WMS and web map tile service data sets appear on the map. Tools are also available for controlling the opacity and order of the layers. Legends, as made available by the SDI provider, can also be viewed by users.

We opted not to include model-based spatial analysis tools in the system, as their effectiveness in collaborative settings is still under debate and has been questioned by some researchers (e.g. Ramsey, 2009), and their use in real-world MSP has been sparse (Pınarbaşı et al., 2017). However, the system enables result data sets from such analyses to be imported, visualised and—if in vector format—edited within the system.

5.3 | Users

Potential users of CGIS in MSP come from a wide variety of disciplines, and the system needs to stay flexible in supporting different tasks that organisers may want to conduct with the system. We designed the system to allow some level of flexibility in defining users and their privileges. The system has three levels of users: anonymous, editors and administrators. Anonymous users can enter the system without user accounts. Editors are required to log in to user accounts, and they can be identified as the creator of any feature they create. Editors can also create new workspaces, making them the workspace owner. Administrators have similar rights to editors, with the exception that they can access the administrator pages. Any level of users can be restricted or allowed to make changes to a workspace. Workspaces can also be configured to allow only specific users to make changes.

5.4 | Workflow

The system was designed around a three-phase workflow. In the pre-workshop phase, the workshop organisers use the system to develop and prepare the tasks for the workshop. User accounts are created for participants, as well as one or more workspaces. The system enables the sharing of workspaces with participants in advance, if needed. In the second phase, during the workshop, the workspaces are used to discuss, draw and edit data. In the post-workshop phase, organisers access workspaces to review and revise results and can export developed vector data sets from the system.

5.5 | The Baltic Explorer prototype

We implemented Baltic Explorer as a web-map application prototype (Figure 4). Web browsers are typically readily available on most commonly used devices, meaning that workshop participants are not required to install new software on their devices. Baltic Explorer utilises the code of the open source web-map application uMap, and as such is based on the Python Django web framework and the Leaflet web map library. The system uses solely open-source components. Among its other features (Table 1), Baltic Explorer has a responsive user interface (UI) design, which also adapts to both touch and mouse input methods. We developed the usability of the prototype to a moderate degree so as to not obstruct the evaluation of its utility. The Baltic Explorer prototype is intended to be used for MSP in the Baltic Sea. Data layers from MSP SDIs (around 800 layers) from the Baltic Sea region were added to the system. Most layers were chosen from Helsinki Commissions (HELCOM's) WMS service, because the service focuses on a large variety of marine data with a coverage of the entire Baltic Sea region. Additional data sets from other sources were added based on requests from MSP actors. Two base maps were added to the system, both from HELCOM.

6 | DEMONSTRATION AND EVALUATION

In the fourth step of the study, the system was demonstrated in a real-world MSP stakeholder workshop in Umeå, Sweden. In the fifth step, the system was evaluated based on naturalistic observation and a questionnaire from the Umeå workshop, as well as a user test conducted in a controlled environment.

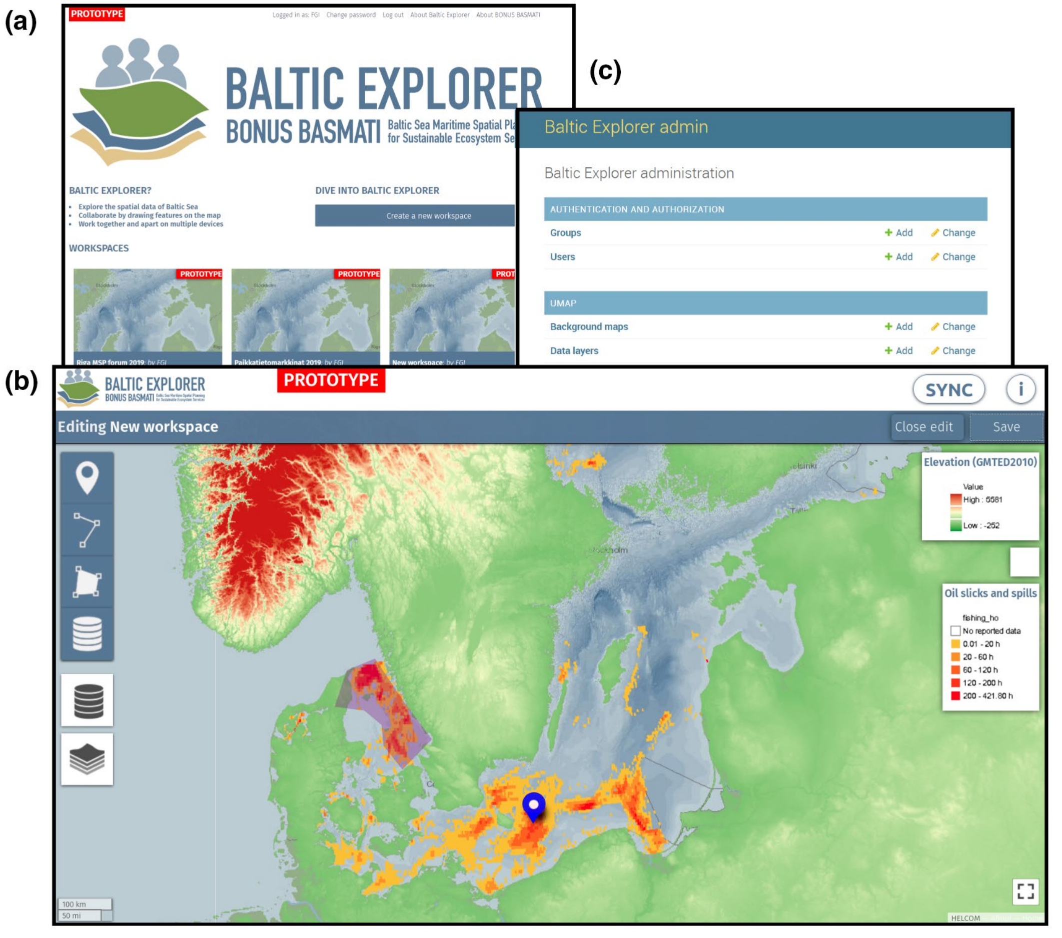

FIGURE 4 Baltic Explorer implementation: (a) login interface; (b) workspace interface; and (c) administration interface

6.1 | Results from the Umeå workshop

The Umeå workshop questionnaire received 16 valid responses, 10 respondents identifying themselves as planners. Respondents considered themselves to be fairly experienced at MSP (scoring 3.44 on average on a scale from 1 to 5) and inexperienced with SDSS (scoring 2.31 on average on a scale from 1 to 5). The answers showed that overlaying data on the map was regarded as the most important tool for four out of six tasks: it "helps in understanding the collaborative planning task", "helps in expressing interests of your sector", "helps in gaining insight into interests of other sectors" and "helps in building trust among collaborators" (Figure 5). The overlay functionality and draw and edit tools had the same number of respondents, who considered them to be helpful in reaching decisions among collaborators.

Out of all the tools asked about in the questionnaire, the feature commenting tool got the most support, being viewed as helpful in promoting constructive decisions among collaborators (Figure 6). It was also viewed as the most helpful of all the tools not yet implemented in the Baltic Explorer prototype. The voting tool was not considered helpful by more than a quarter of the respondents for any of the tasks. The chat box was considered to be helpful by more than half of the respondents in helping to promote constructive discussion across sectors and helpful in understanding the collaborative planning task. Five respondents felt neither of the tools implemented in

TABLE 1 Summary of features in Baltic Explorer

Feature	Details	Interface
Multi-user workspaces	Enables users to work together from multiple devices within closed map-based environments and store their progress	Login interface (creating new workspaces and access to existing workspaces) Workspace interface
Pan and zoom + scale bar	Navigating the map	Workspace interface
Workspace synchronisation	Updates new features and changes made by other users to the user´s view	Workspace interface
Draw and edit vector features	Vector data can be drawn, edited and stored in workspaces which can serve multiple needs, for example visualising objects that are missing from data layers	Workspace interface
Vector layers	Vector layers store vector features. Can also be used to organise vector data, for example based on users or themes	Workspace interface
WMS data access (overlay layers)	Enables users to easily access a wide selection of marine data from varying sources	Workspace interface
User accounts	User accounts enable identifying creators of different contents and defining access and edit rights for workspaces	Login interface
System administration	Managing: Users (delete/add), Workspaces (editing properties including name, data layers, editor users, etc.), WMS data (add/remove), Vector layers (deleting and moving data between workspaces)	Admin interface, Workspace interface (basic-level workspace and vector layer management)
Easy-to-use interface	Simplified interface. Large buttons. One-click overlays on and off the map. Familiarity (similar interface to other popular map applications)	Login interface Workspace interface
Adaptive (responsive) design	The view adapts to use with different screen sizes, including mobile devices. Functionalities usable on both touchscreen and mouse and keyboard input	Login interface, Workspace interface

Baltic Explorer was helpful in building trust among collaborators, although one of these respondents felt that the feature commenting tool would be helpful for the task. Three respondents felt that neither of the tools in Baltic Explorer was “helpful for reaching decision among collaborators”. However, one of these respondents felt that the “voting tool” would be helpful for the task. Two respondents felt that neither of the tools in Baltic Explorer was helpful for promoting constructive discussion across sectors, although both respondents felt that a feature commenting tool could be helpful for the task. For each of the remaining three tasks, a single respondent felt that neither tool implemented in Baltic Explorer would be helpful. However, for understanding the collaborative planning task, one of these respondent felt that a “chat box” would be helpful, while for gaining insight into interests of other sectors, one of the respondents felt that both the feature commenting tool and the voting tool would be helpful.

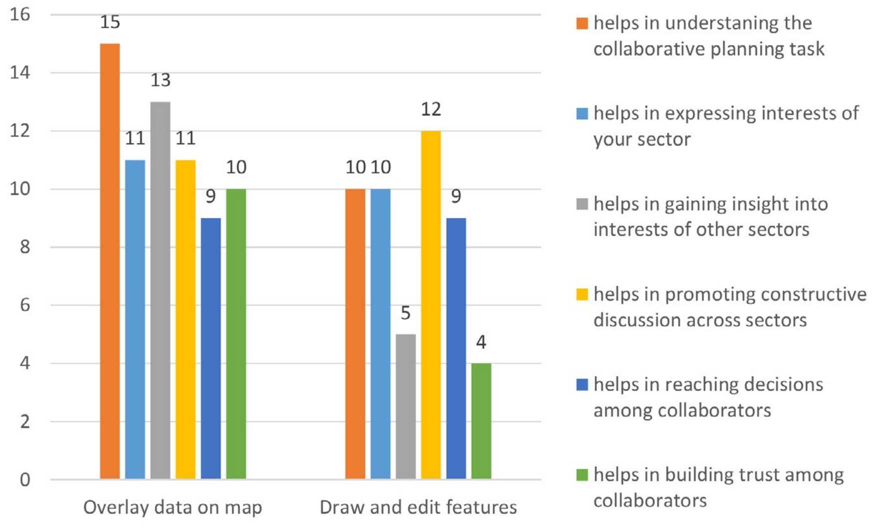

FIGURE 5 The number of respondents who considered the existing tools of the Baltic Explorer prototype to be helpful in various tasks (N = 16)

We calculated an average helpfulness index of each tool across the six tasks for both planners and non-planners as $\sum x_{tr} / (n_t n_r)$, where $\sum x_{tr}$ is the total number of times that respondents considered the tool to be helpful for a task, n_t is the number of tasks and n_r is the number of respondents (Figure 7). Participants who identified themselves as planners viewed the "draw and edit" tool, the "feature commenting" tool, the "voting tool" and the "chat box" to be on average more helpful than other users, while those other than planners viewed the "overlay data on map" feature as more helpful than planners. The empirical basis is too small to draw conclusions, but it indicates that the potential use content is an important background factor for evaluations, in this case planner/non-planner.

Ten respondents left open comments about the Baltic Explorer prototype. Four respondents commented that the system was either missing some critical data or that they hoped for more data in the system. One respondent commented that the data and its scale are crucial, while another respondent pointed out the importance of including metadata for data layers. Two respondents felt that the usability of finding data sets from the overlay menu needs to be improved, while a third respondent felt that it should be easier to identify what data is available in the system. One respondent also commented on colour choices of the data layers and identified issues in viewing legends for the layers. One respondent felt that the usability of the polygon draw tool was poor. One respondent asked for the system to be linked with other SDSS for MSP. One respondent commented that the tool is useful in discussions with people you do not know. One respondent requested to be able to add WMS layers from the workspace interface, and that the save functionality should be separate for data layers and the workspace.

During the interactive session, it was observed that users had difficulties in using the system with mobile phones and tablets, which ultimately made them use the system with laptops only. Users also had difficulties in creating new layers for vector objects. Some users did not realise that the map could be zoomed, as zoom buttons had not been added to the interface. To overcome usability issues, users helped each other with the use of the system, and in some cases a GIS expert had to step in to help the participants. Participants noted the absence of metadata for WMS data layers, which they considered to be a necessity. For example, users did not know if the data was up to date. During the workshop, there were also requests for additional data to be included in the system. Participants also noticed a spatial mismatch between data layers.

In one instance, two participants were observed discussing the location of a bridge between Umeå, Sweden, and Vaasa, Finland. The Baltic Explorer prototype enabled them to draw the bridge on the map and move its

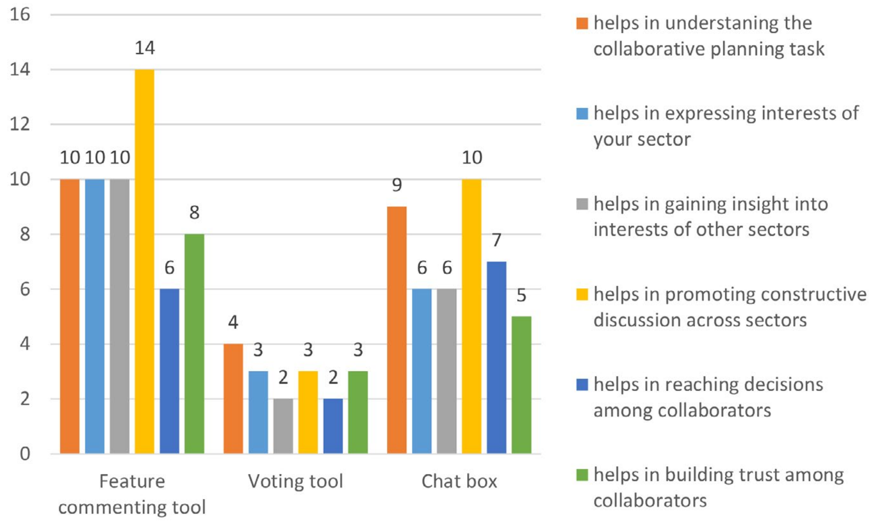

FIGURE 6 The number of respondents who considered potential non-implemented tools to be helpful in varying tasks

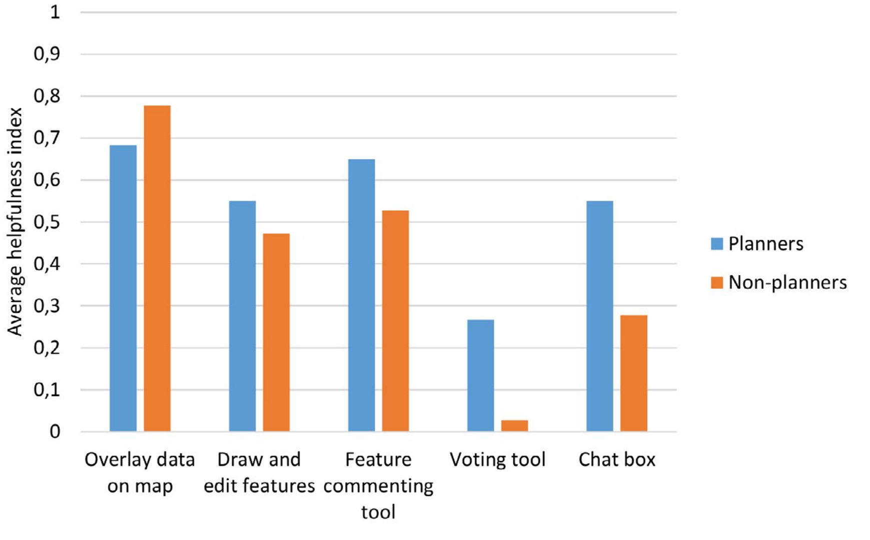

FIGURE 7 The average helpfulness of tools as considered by respondents who identified as either planners or non-planners

location based on their discussion (Figure 8). In another instance, participants were discussing how far wind turbines can be seen from the coast. The system was unable to support the discussion, and there was no general agreement on the matter. One participant noted that if the system could visualise the size of wind turbines, that feature could be useful.

During the workshop, participants commented that to be able to visualise and draw together was important. It was also commented that the system was able to take the discussion forward. One participant also commented that to be able to share data was critical.

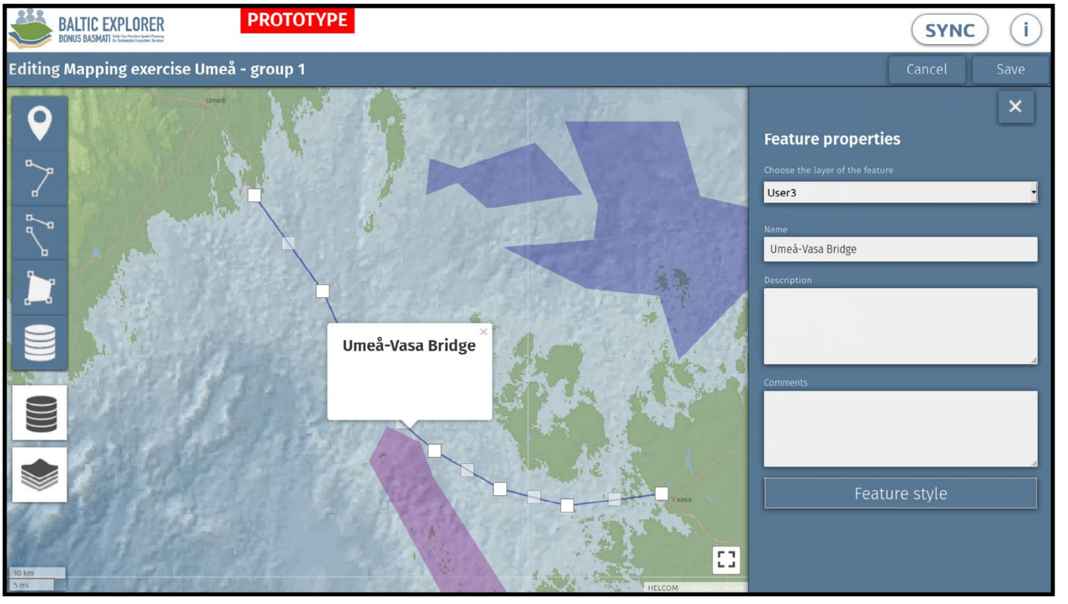

FIGURE 8 In the real MSP user test, participants had a discussion facilitated by Baltic Explorer about a bridge between the cities of Umeå, Sweden, and Vaasa, Finland

6.2 | Results from the controlled environment user test

All 18 participants in the controlled environment user test responded with valid answers to the questionnaire presented to them. The results showed that there was a difference in how users perceived the support each device provided for tasks, depending on whether they had both device types available or only one of them (Figure 9). When users only had a single type of device available, they perceived the devices to be relatively well suited to each type of task, compared to when they had both devices available.

The overall results show that users regarded the personal screen to be more suitable for the task of preparing to present their interest. The shared device was perceived to be more suitable for the task of presenting their interests. Both the personal and shared device were regarded as equally suitable for the tasks of gaining insight into others' interests and collaborating to find compromises. However, the differences came mainly from the answers from the groups with both types of devices available. PhD students and professionals preferred different devices for the tasks of gaining insight into the others' interests and collaborating to find compromises (Figure 10).

Six respondents left open comments related to the usefulness of the Baltic Explorer prototype. Three respondents commented that the draw point features tool was difficult to use or did not perform as expected. One respondent requested automatic syncing of views, while another commented that it would be fun to include a freehand draw tool. One respondent from the group using both a personal and a shared screen requested other communication tools such as text boxes and discussion panels.

7 | DISCUSSION

With paper maps still being widely used in MSP workshops rather than digital tools, there is clearly a need to better understand what type of systems could better support these settings. Our review of the scientific literature revealed that while there are a wide variety of tools for MSP, these tools do not appear to meet the requirements that would make them widely used in real-world collaborative MSP processes. Tools in collaborative MSP need

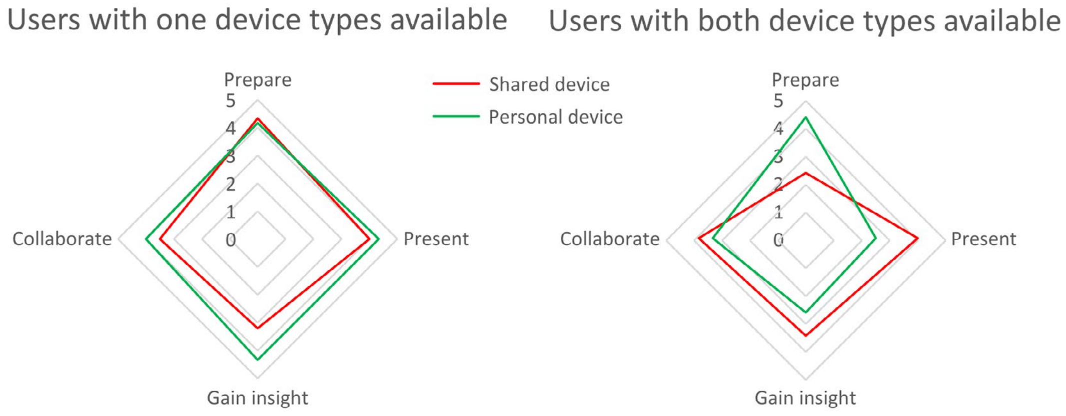

FIGURE 9 Users with a single device type were satisfied with their devices. However, users with a choice between devices had clear preferences on which to use for different tasks

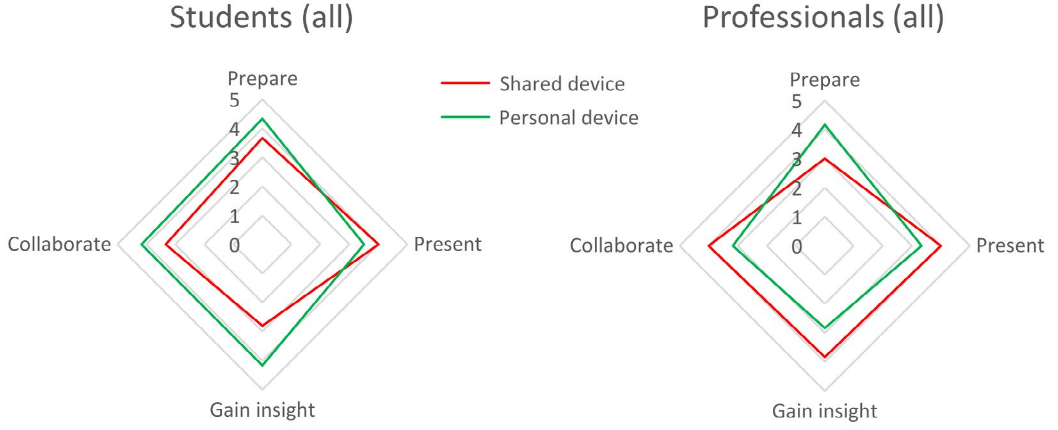

FIGURE 10 On average the nine PhD students preferred the personal devices for three out of four tasks, while the nine professionals preferred the shared device for three out of four tasks

to enable multiple users to simultaneously interact with the system. They need to be simple and easy to use for novice GIS users. They need to be flexible with data from various data sources and provide tools that planners can use for a variety of workshop tasks. The design of Baltic Explorer builds on these requirements. It offers a collaborative platform for MSP actors that is easy to use and includes simple spatial tools for a wide variety of tasks in MSP workshops. Its flexibility and focus on exploration of data sets offer freedom that is not typically found in other tools for MSP. These features, combined with the multi-user map workspaces, offer MSP stakeholders a new way of collaborating in workshops.

7.1 | Utility of the designed functionalities in use cases

The user tests revealed some usability issues, including issues with using the mobile user interface, and difficulties in finding relevant data layers from the overlay data menu. These issues should be improved to provide a smoother experience for the system's users. Despite these usability issues, the Baltic Explorer functionalities and multi-user interactive map environments were demonstrated to successfully facilitate discussions in a real-world MSP workshop. For example, in the Umeå–Vaasa bridge case, the draw and edit tools were used to visualise the bridge and, based on the discussion, to change its position. The questionnaire provided additional support for the utility of the tools, as most respondents considered both the overlay data and draw and edit tools to be helpful in various tasks. The overlay data tool should be improved by adding metadata. The responsibility for metadata lies both with the developer and the data provider: on the one hand, the developer must add the functionalities that enable the metadata to be added; on the other hand, to enable easy access to the metadata, data providers should add the metadata to the layers' attributes in the WMS server. The aim should be to provide a comprehensive CGIS that can support the various needs of MSP workshop participants, and it was found that the Baltic Explorer prototype could benefit from further functionalities. Based on the results from the Umeå workshop questionnaire, the tools implemented in Baltic Explorer were found to be helpful by most workshop participants in various ways, including expressing one's interests and promoting constructive discussion. However, for all tasks in the questionnaire, at least one participant felt that neither of the tools was helpful. A separate commenting tool, a voting tool, and a chat box could cover some of the gaps left by the tools implemented. In particular, a feature commenting tool and a chat box were considered by a significant number of participants to be helpful in various ways. In contrast, a voting tool was not considered to be helpful by most respondents. However, as these tools are not implemented in Baltic Explorer, these results should still be verified in the future through demonstration and evaluation in real-world use. The use case in the Umeå workshop is likely to have influenced how the participants viewed the helpfulness of tools. Thus, in other use cases, the voting tool could potentially be considered as more desirable. Testing the tools in real-world use cases can also reveal how users use these tools and what kind of support the tools provide.

More data was a highly requested improvement. The need for additional data was expressed a number of times during the Umeå workshop. While, in general, users were able to understand the system well enough to use most of its capabilities, the administration interface was not used by the organisers to add data to the system. As the organisers had spent little time in getting familiar with the Baltic Explorer prototype in advance, they appeared to be unaware of the capabilities of the administration interface. In general, while the organisers may become more experienced with a system once they have been using it more, they should be considered as novice GIS users. To support this, the most important functionalities from the administration interface in the Baltic Explorer prototype should be made easier to use and moved to the workspace interface.

As users were able to view and edit all features created by other users and to change WMS data layers on the map, both user tests revealed the need to better understand user privilege issues in CGIS. On the one hand, users can benefit from having the freedom to edit features produced by other users and to access all available data. However, the workshop organisers need to be able to maintain control over actions in the workspace and participants need to trust that what they draw or add to the map will not be removed or edited by other users. Users could also benefit from having control over the visibility and storage of the data they add, as they may need to discuss sensitive data that they do not want stored in the system. In the Baltic Explorer prototype this could be achieved through enabling data from web feature services to be imported to the view, which would keep the data in the provider's servers while enabling its visualisation and editing with the system. Similarly, it should be carefully considered what information is stored about users, and whether there is a need to have anonymous access to some functionalities in the system.

The results from the controlled environment user test revealed that users may perceive both types of devices as being supportive of multiple different tasks that may be part of the MSP stakeholder workshops. The results also show that when users are not aware of alternative devices, they may feel that the devices they are using work well for the tasks they are doing. However, should the users be presented with alternative device types, they may have a clear device preference for each task. The results indicate that different user groups may prefer to use different devices for tasks. However, due to the small sample size, more research should be conducted to verify these results. Nevertheless, the results from the controlled environment user test indicate that users can benefit from both types of devices, and it is recommended that users have the option to use both.

Several challenges were identified in studying the utility of CGIS for MSP. Input from end users is often regarded as critical for building effective systems. However, there may be neither the desire nor the incentive for MSP workshop organisers to participate when the system is still being developed and cannot provide immediate support for their activities. Also, the number of real stakeholders in planning workshops may be too low to generate meaningful statistical analyses of the findings (Arciniegas & Janssen, 2012). Finally, a single MSP workshop provides data from a single use case. Comprehensive testing may be impossible without broad interest from the organisers of MSP workshops. The results also indicate that participants may evaluate tools in the context of how they would use them in their working practice. Therefore, it seems that response to the effectiveness of tools may be influenced by the respondents' background.

7.2 | Gaps in knowledge

The requirements review enabled a science-based design of a CGIS in MSP to be developed. The requirements review also revealed that there are many notable gaps in knowledge about developing effective CGIS for MSP. The ill-defined nature of decision-making processes such as MSP makes it difficult to define the use cases of CGIS that are to support it. More research is thus needed into how spatial data is used and managed in real MSP workshops, which will help to understand what additional functionalities are needed in systems like Baltic Explorer. Also, a better understanding of different types of end users, their GIS competencies, their role (planners/non-planners) and perhaps other factors could help focus the tools and possibly differentiate the available functionalities according to user groups and specific tasks.

Currently there appears to be a conflict of opinion on whether model-based spatial analyses should be used in CGIS for MSP. Facilitating discussions through these analyses requires common understanding of the issue and solutions among all participants. The complex nature of many analyses may make them unsuitable for CGIS. For simpler model-based spatial analyses, new methods are needed for implementing them in such a way as to help non-expert participants in understanding them in the short time available in workshops.

7.3 | Beyond MSP workshops

Baltic Explorer is designed for MSP stakeholder workshops where users collaborate in the same space at the same time. However, with a change of data, the design could be used for other collaborative use cases as well. Also, the web-based implementation of the Baltic Explorer prototype enables remote use. Users could also collaborate at different times. Several studies have noted the utility of such working methods in MSP. For example, Merrifield et al. (2013) note that online data exploration tools are a critical first step in MSP, enabling visualisation of data for non-experts and trans-boundary communication of spatial information. Pınarbaşı et al. (2017) argue that real-time online participation systems are needed for MSP in the future. Shucksmith, Gray, Kelly, and Tweddle (2014) also used an online data visualisation tool based on Google Earth in the MSP context in a different time, different location manner to consult the public about the completeness and accuracy of the data, which ultimately helped to fill some important data gaps. In addition, Baltic Explorer could be used online without the need for users to interact with it. For example, Collie et al. (2013) recognised tools that allowed stakeholders to submit their own plans for consideration to be useful. With a wider variety of use cases, a system is more likely to be adopted in real MSP (Pınarbaşı et al., 2017). Integrating such functionalities would make the system a comprehensive PGIS for all aspects of participation and collaboration in MSP.

In the future, aspects such as maintenance and funding will also need to be considered. Baltic Explorer is implemented with free and open source components, which enables its own code to be distributed as fully free and open source, and other organisations and individuals to run their own versions of the system. Nevertheless, future motivation to maintain servers and update the system will be dependent on continued need for and use of the system.

8 | CONCLUSIONS

The primary aim of the study was to develop knowledge that can be applied in developing useful functionalities in CGIS that enhance same time, same location collaboration in MSP. By defining requirements, designing and developing, as well as evaluating a CGIS for MSP, we were able to develop knowledge that helps to better understand the utility of such systems' properties in MSP. It was demonstrated that the available functionalities in Baltic Explorer are enough to facilitate discussions in collaborative work in MSP workshops. However, the results from the study also highlighted some shortcomings in these functionalities that prevent their full effectiveness; and it was observed that additional functionalities (such as a way to visualise wind turbines) could improve the usefulness of the system. Future research should also focus on filling other gaps in the knowledge of CGIS for MSP, including possible use cases, whether or not model-based analysis tools can be integrated into the real-world use of such systems, and what other additional features can further enhance the effectiveness of CGIS for real-world MSP.

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